(12) UK Patent Application (19) GB (11) 2 047 874 A

(21) Application No 8007296
(22) Date of filing 4 Mar 1980
(30) Priority data
(31) 2910568
(32) 17 Mar 1979
(33) Fed. Rep. of Germany (DE)
(43) Application published 3 Dec 1980
(51) INT CL[3] F28F 21/06 1/00 // 7/02
(52) Domestic classification F4S 12 1 2A1 2A2 2A3 2B11 2B1 2M10 2M11 2M1 2M6 2M9 5EX 9 B5B 351 352 357 358 35Y 360 361 363 368 FB
(56) Documents cited
DE OLS 2833493A
GB 1514577
GB 1483414
GB 1417282
GB 1305330
GB 1262187
GB 1237389
GB 1129321
GB 1085938
(58) Field of search B5B F4S
(71) Applicant
Akzo N.V., Arnhem, Ijssellaan 82, The Netherlands
(72) Inventors
Helmut Stohr,
Klaus Gerlach,
Erich Kessler,
Klaus Schneider,
Karl Ostetag
(74) Agent
Elkington and Fife

(54) An Apparatus in which Heat is transferred through Hollow Threads as well as Hollow Threads suitable for this purpose

(57) Hollow threads are composed of synthetic polymers having from 10 to 90% by volume of inter-communicating pores and an even surface containing open pores. The proportion of the surface of the threads which has such pores amounts to from 10 to 90%. The threads may be used in heat exchangers, filters, oxygenators and in chemical apparatus.

GB 2 047 874 A

Best Available Copy

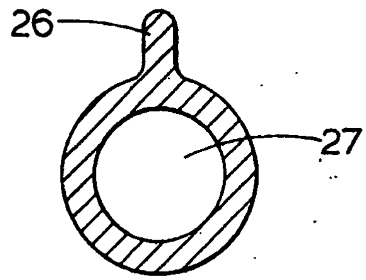

Fig.1

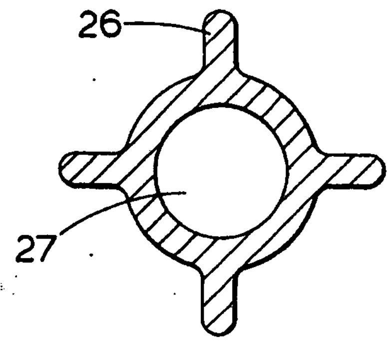

Fig.2

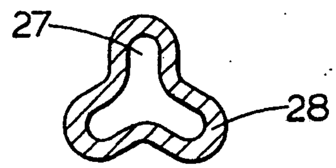

Fig.3

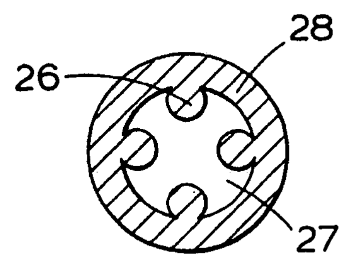

Fig.4

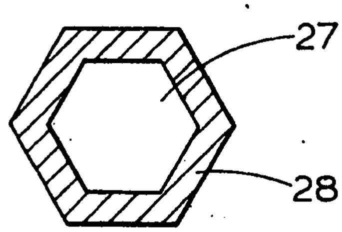

Fig.5

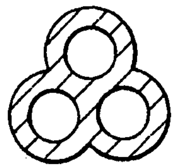

Fig.6

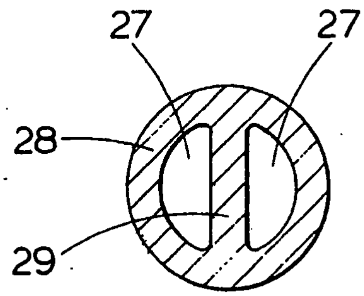

Fig.7

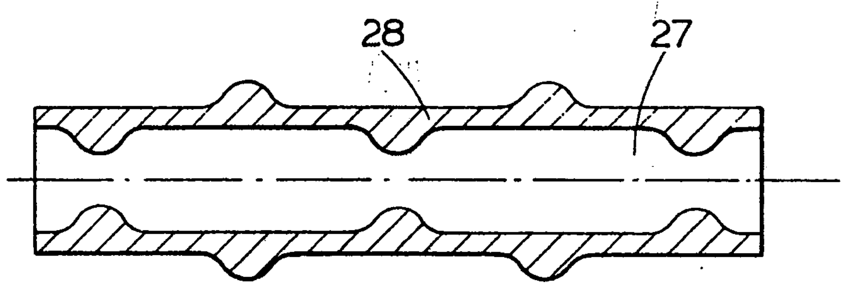

Fig.8

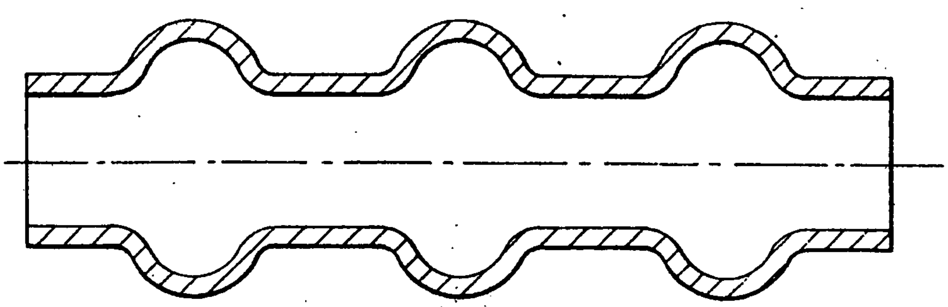

Fig.9

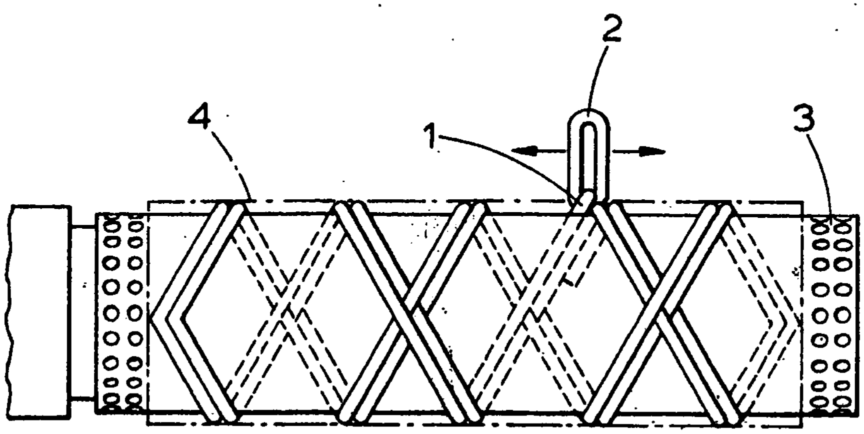

Fig.10

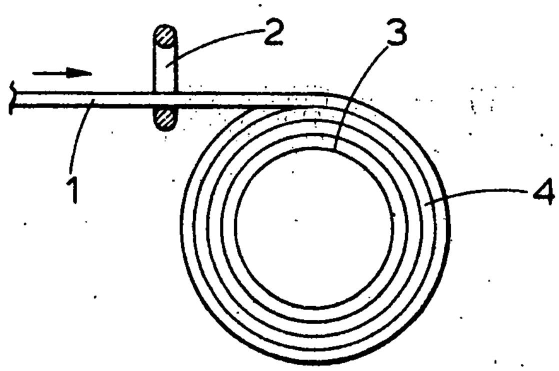

Fig.11

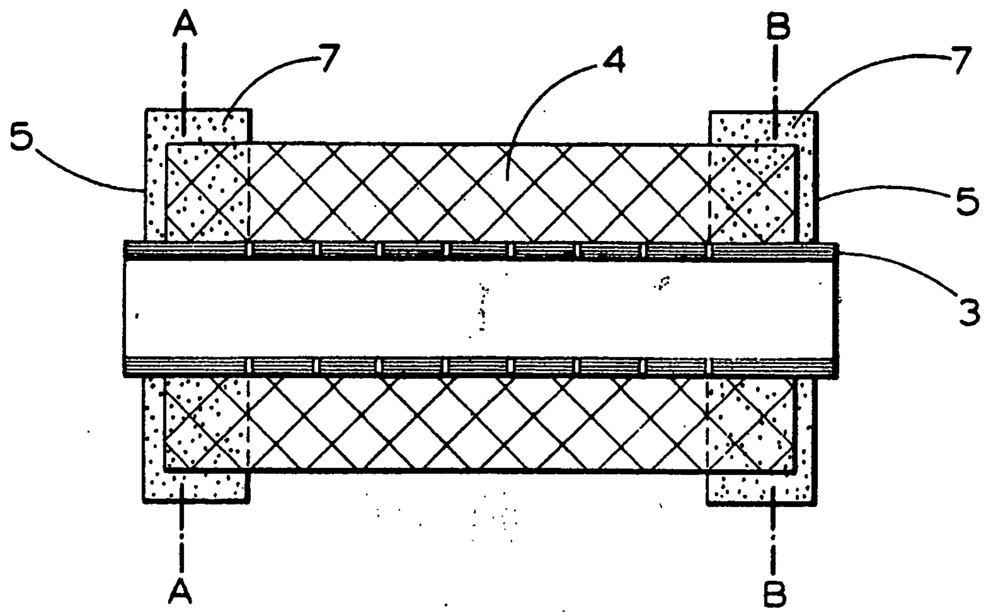

Fig . 12

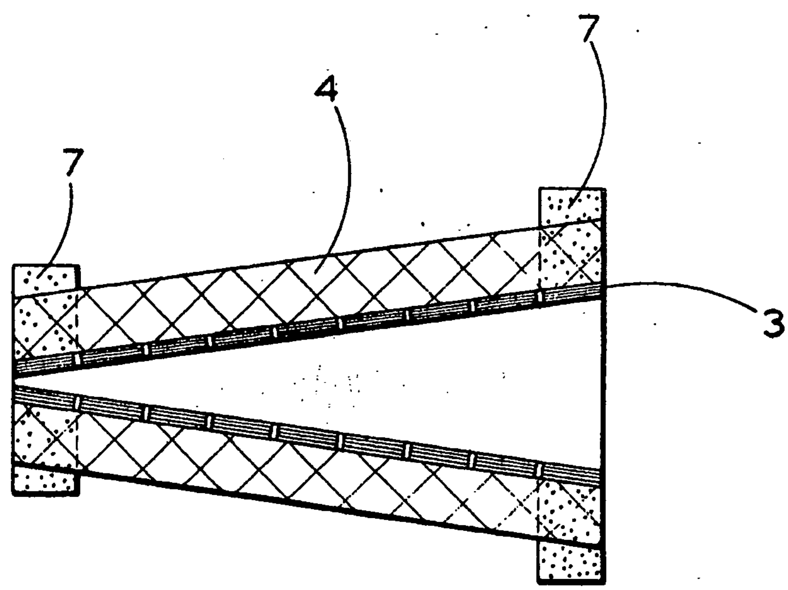

Fig . 13

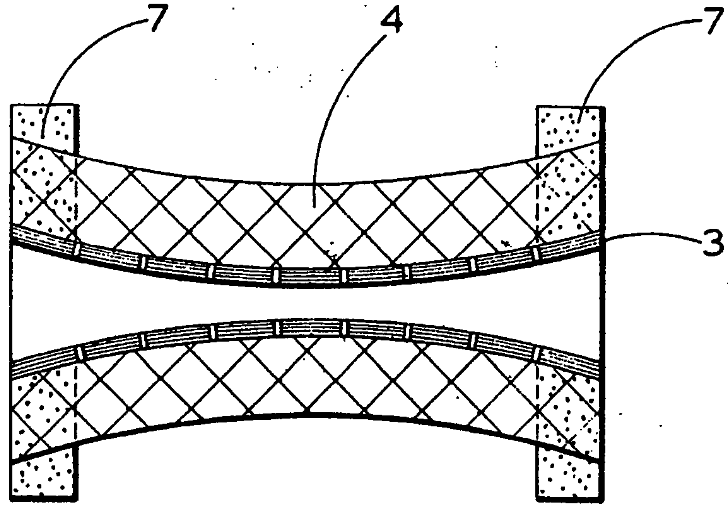

Fig . 14

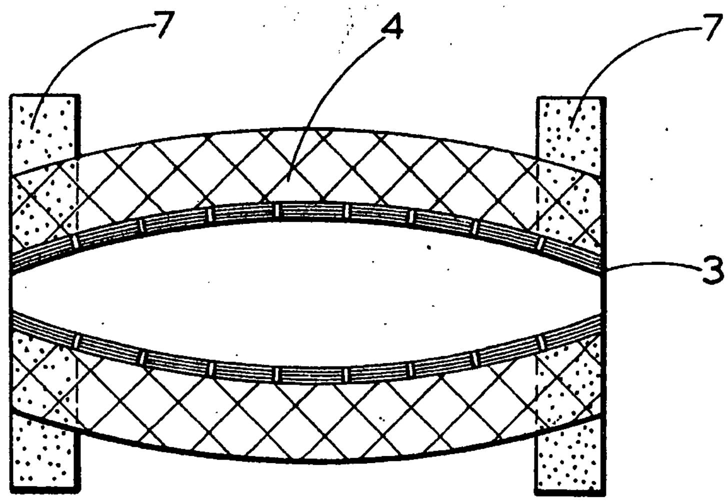

Fig . 15

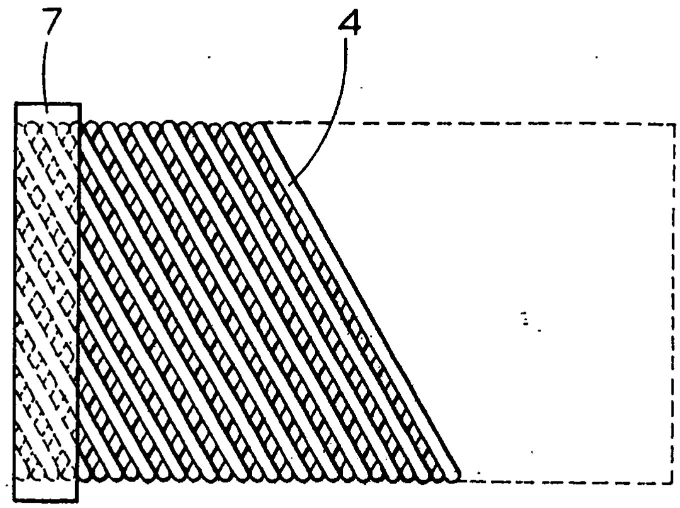

Fig.16

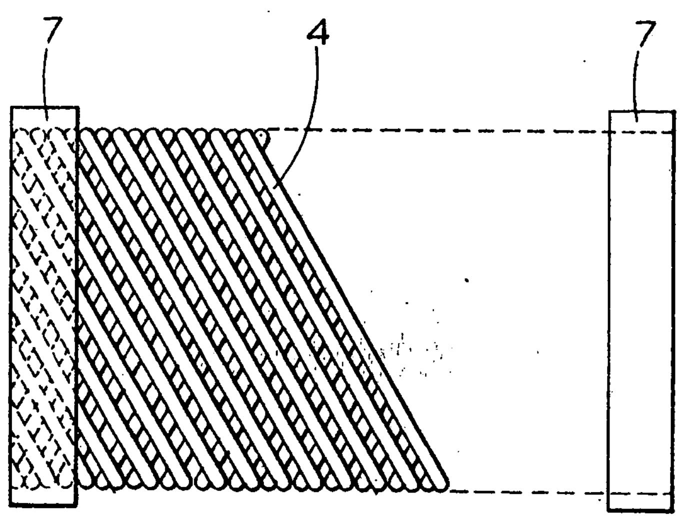

Fig.17

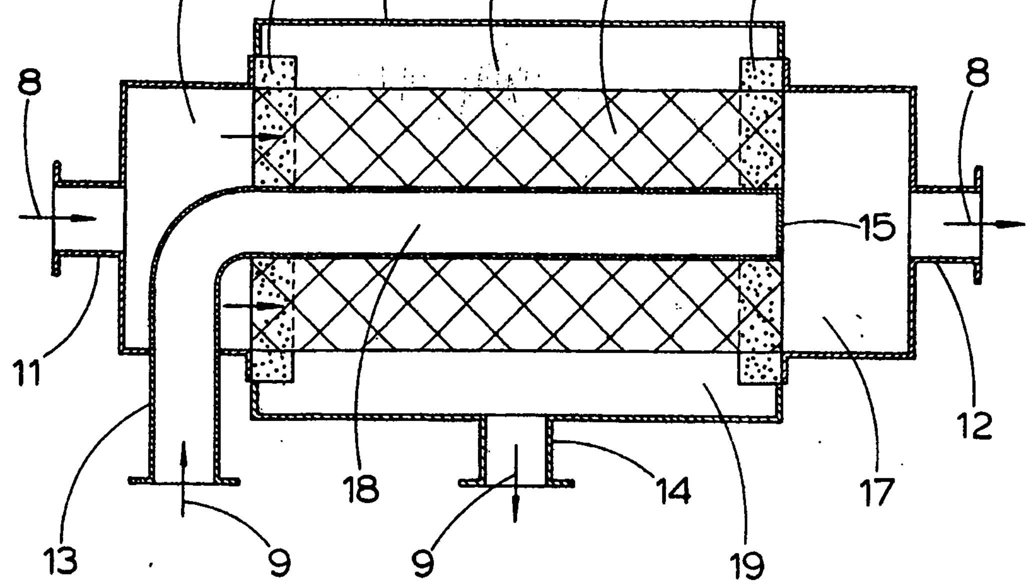
16
7
10
19
4
7
8
8
15
11
12
13
9
18
9
14
19
17

Fig.18

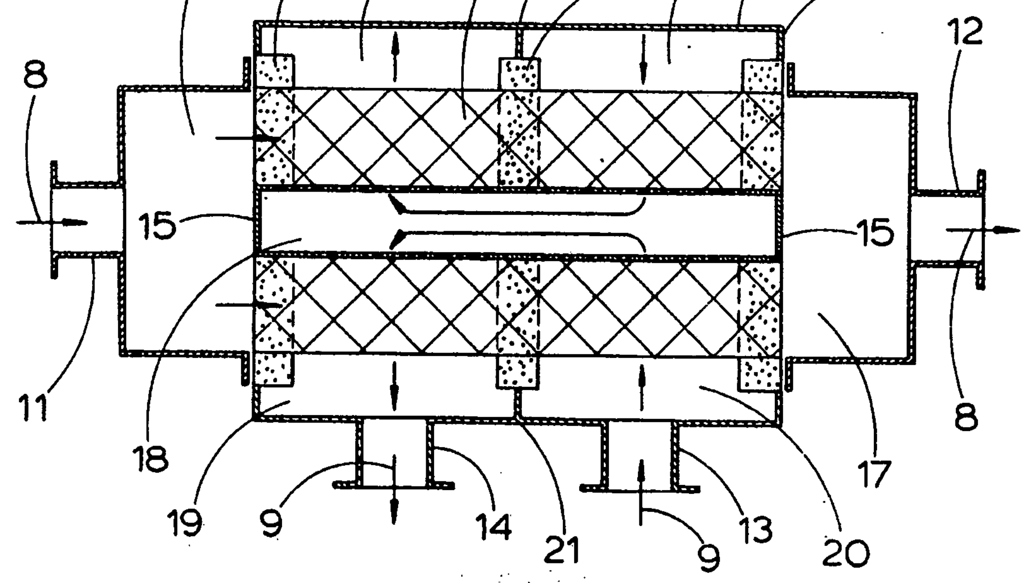
16
7
19
4
21
20
10
7
7
12
8
15
15
11
18
19
9
14
21
9
13
20
17
8

Fig.19

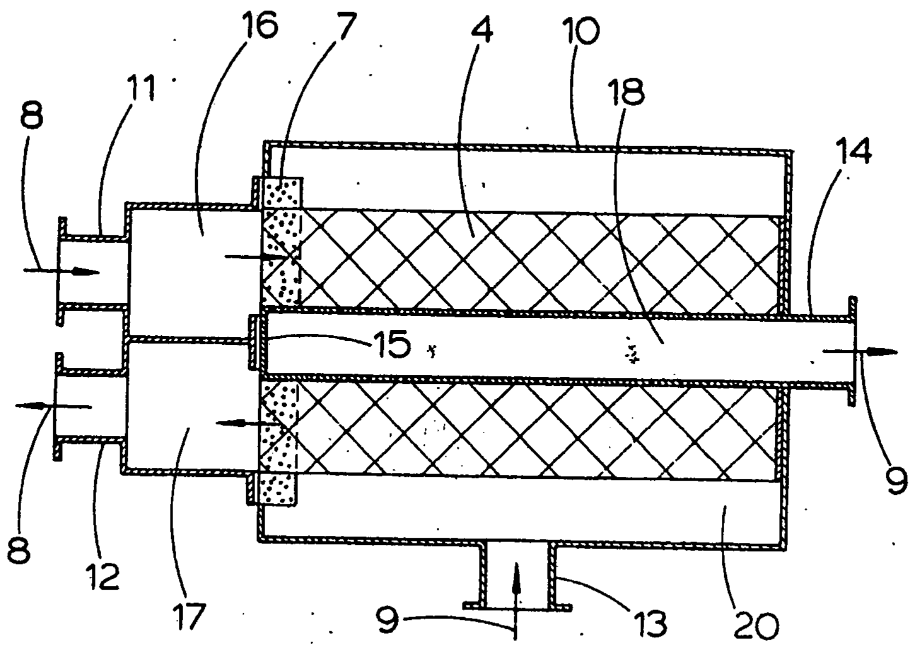
16
7
4
10
11
8
18
14
15
9
8
12
17
9
13
20

Fig. 20

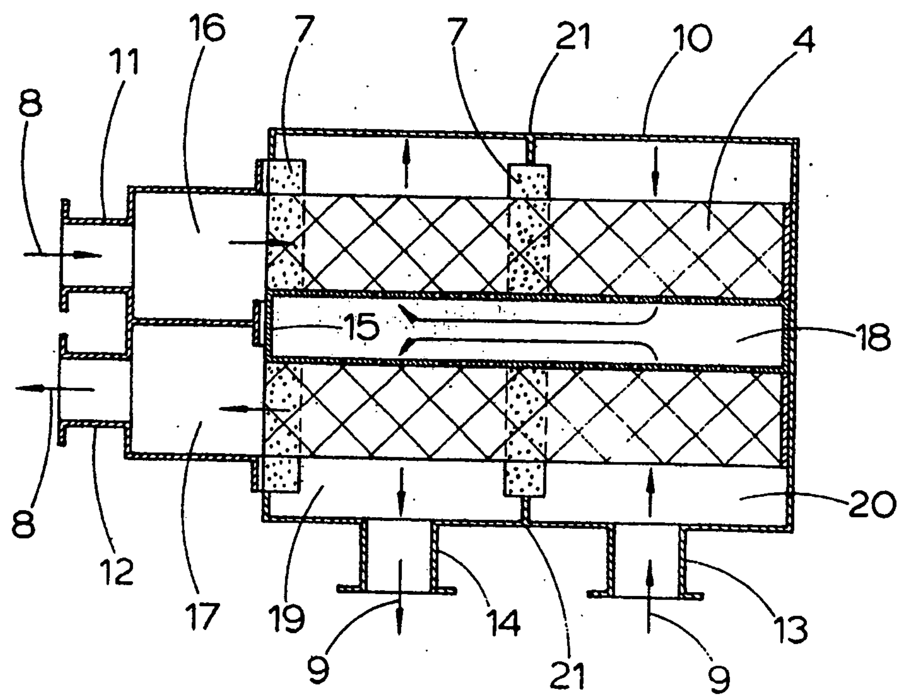
16
7
7
21
10
4
11
8
15
18
20
8
12
17
19
14
9
21
9
13

Fig. 21

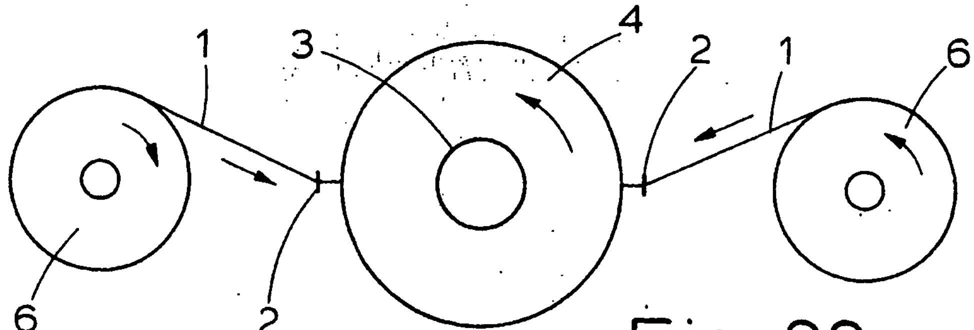

Fig. 22

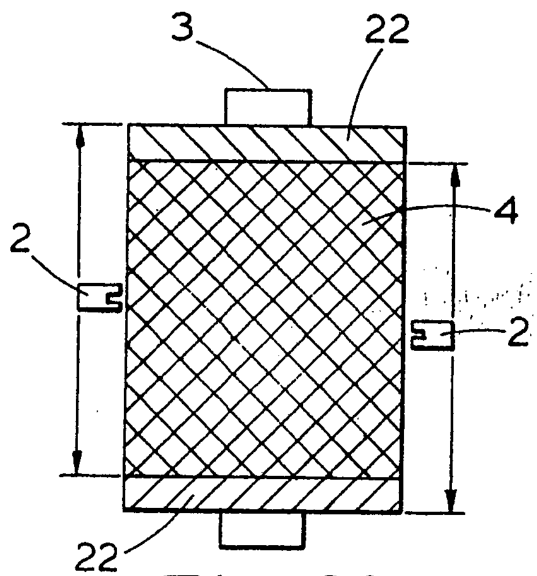

Fig. 23

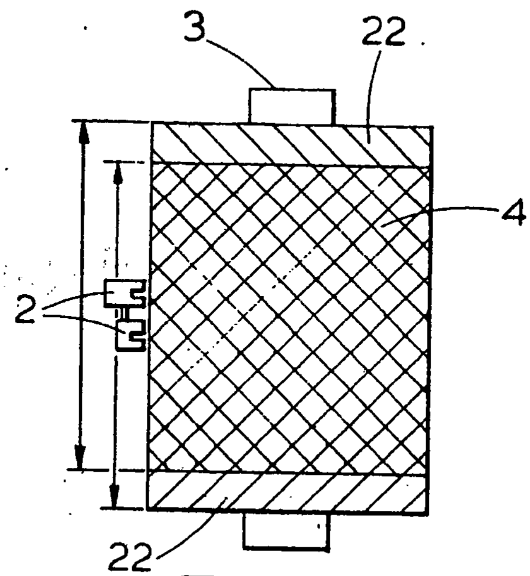

Fig. 24

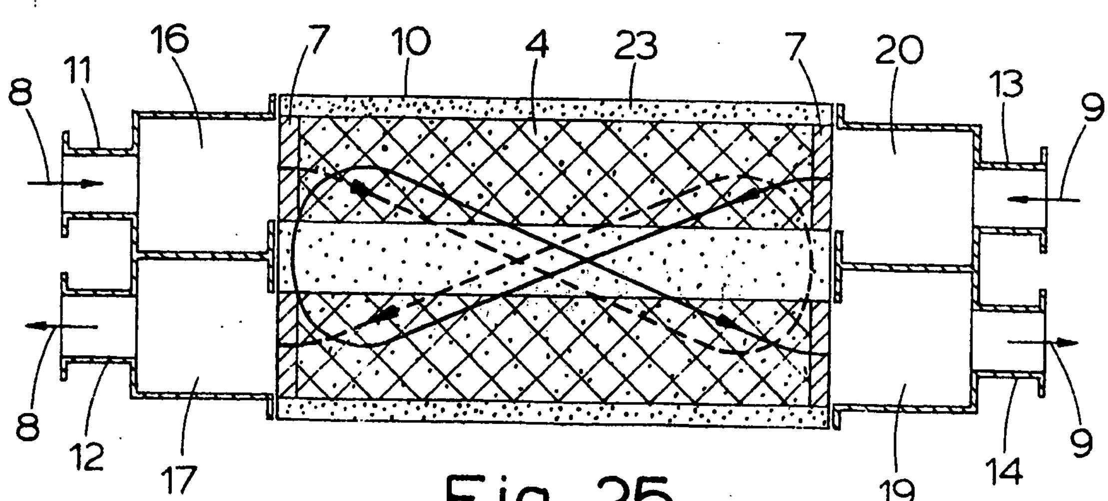

Fig. 25

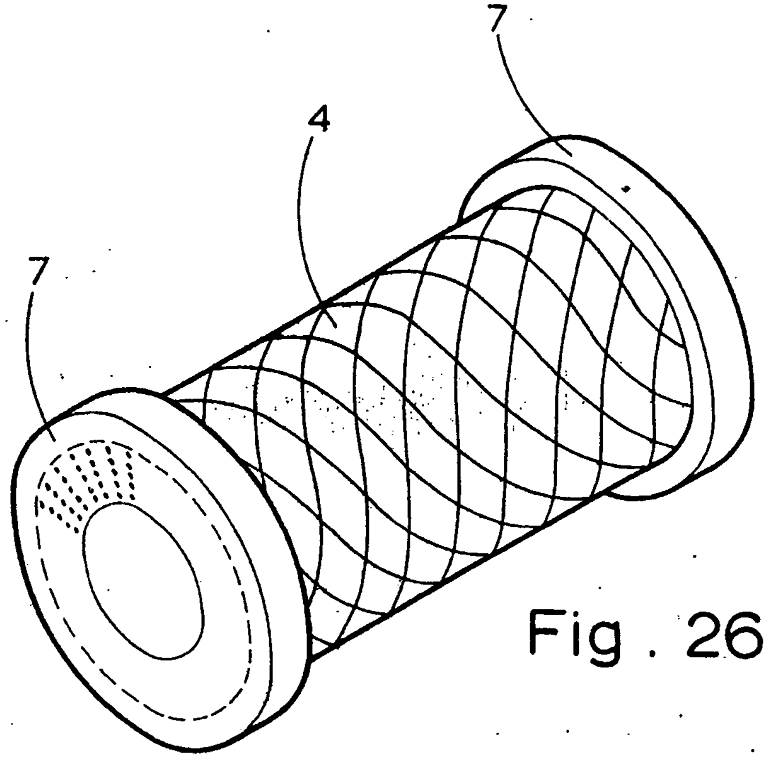

Fig . 26

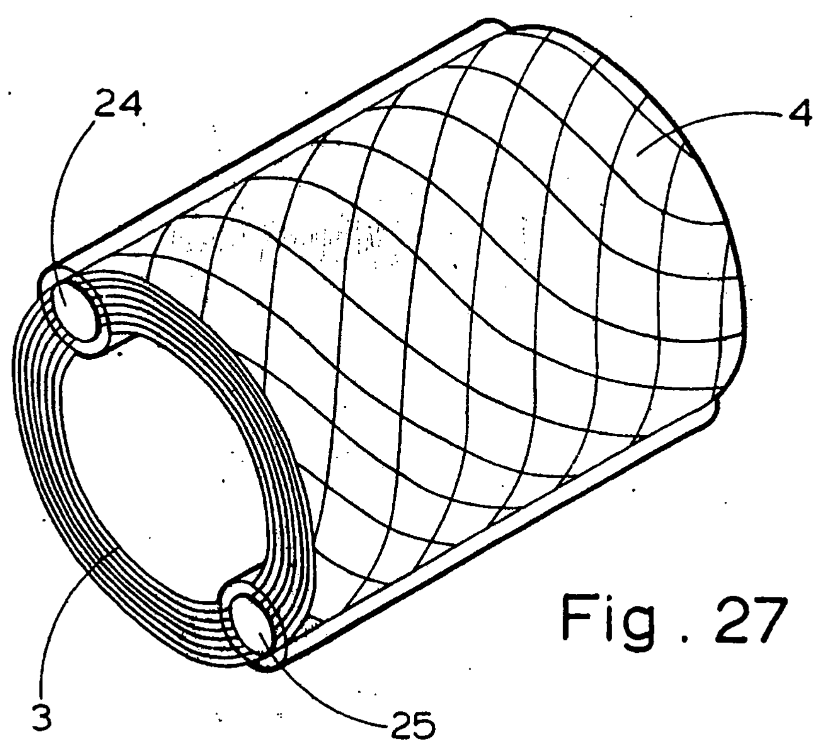

Fig . 27

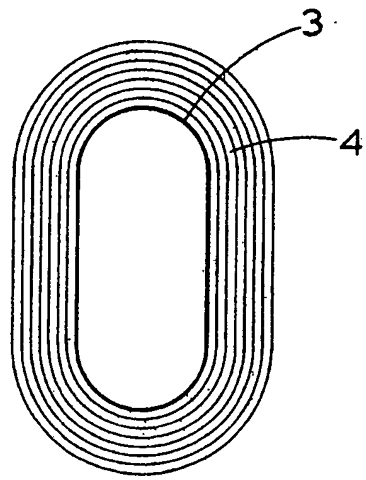

Fig.28

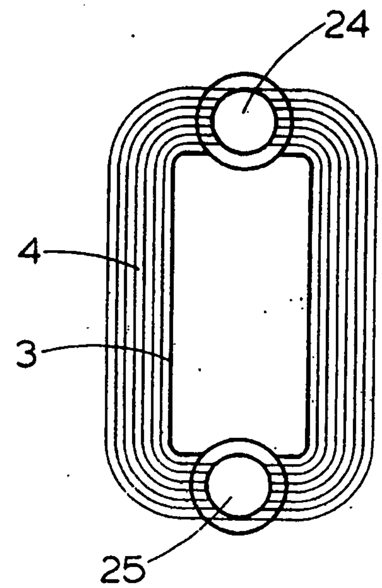

Fig.29

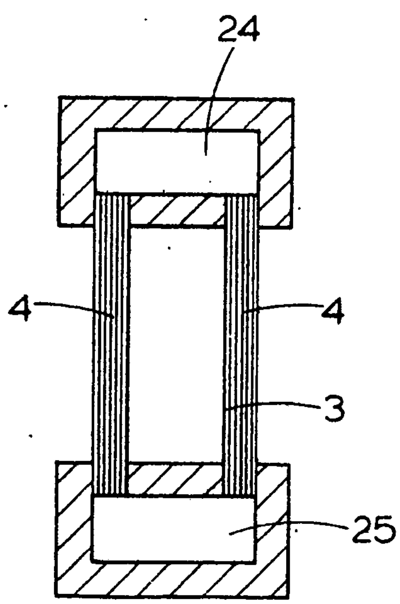

Fig.30

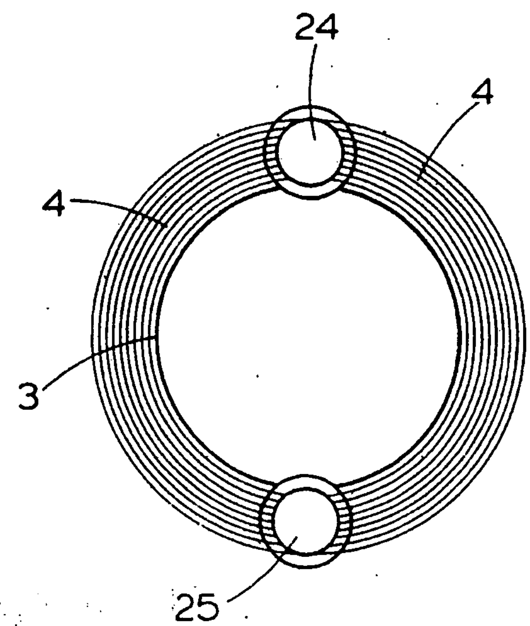

Fig.31

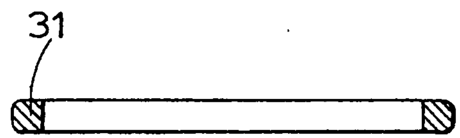

Fig. 32

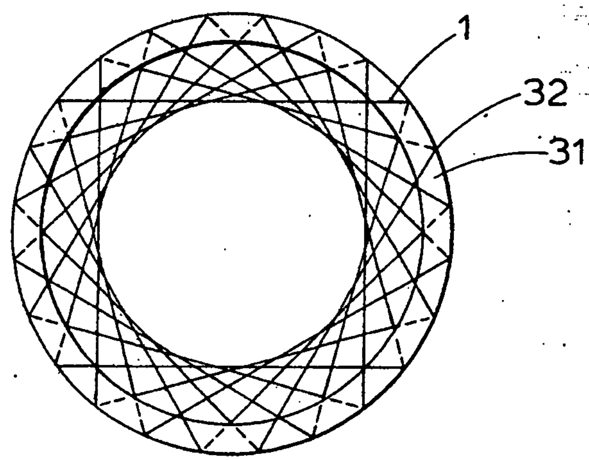

Fig. 33

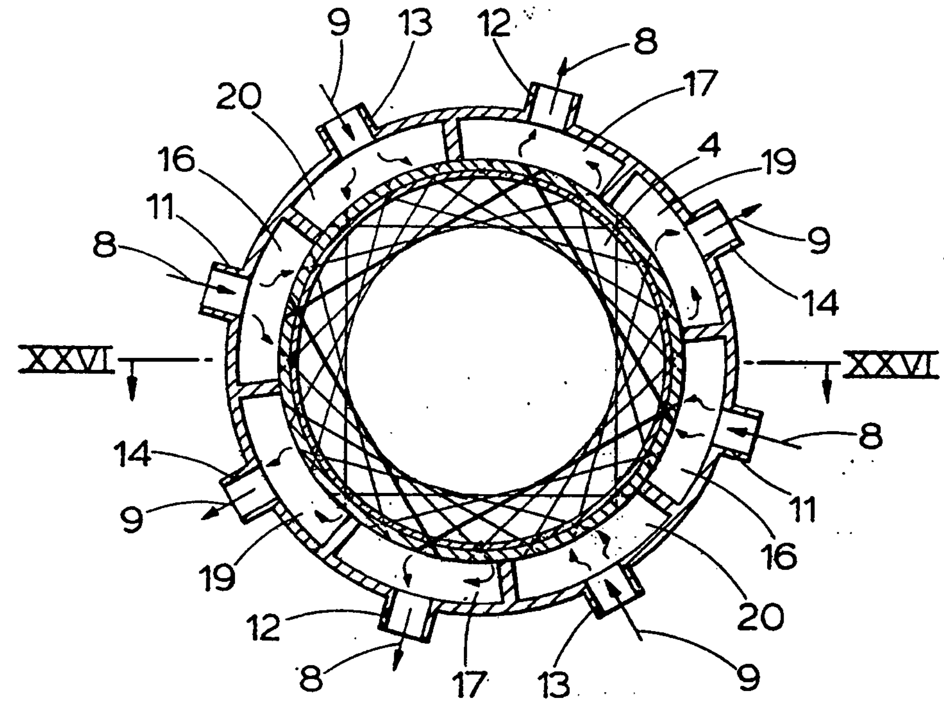

Fig. 34

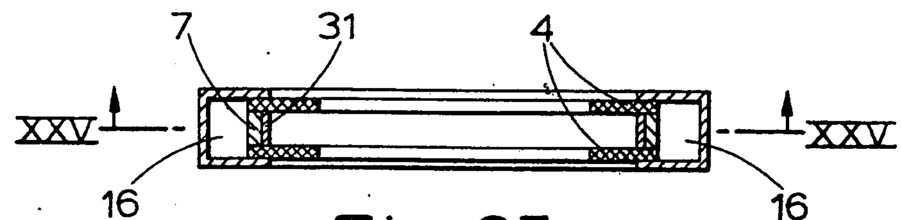

Fig. 35

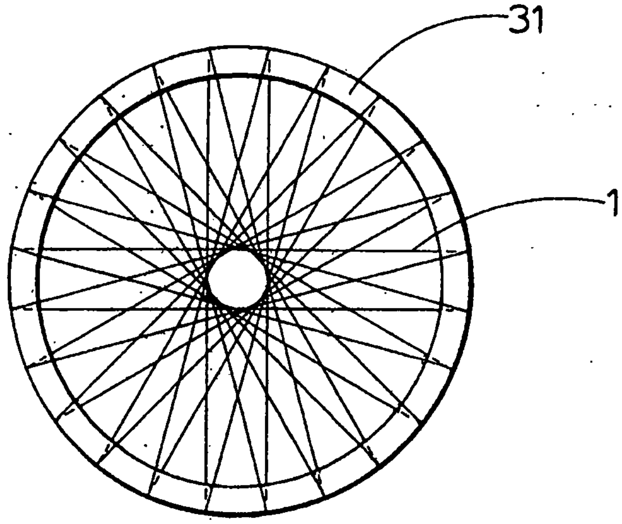

Fig . 36

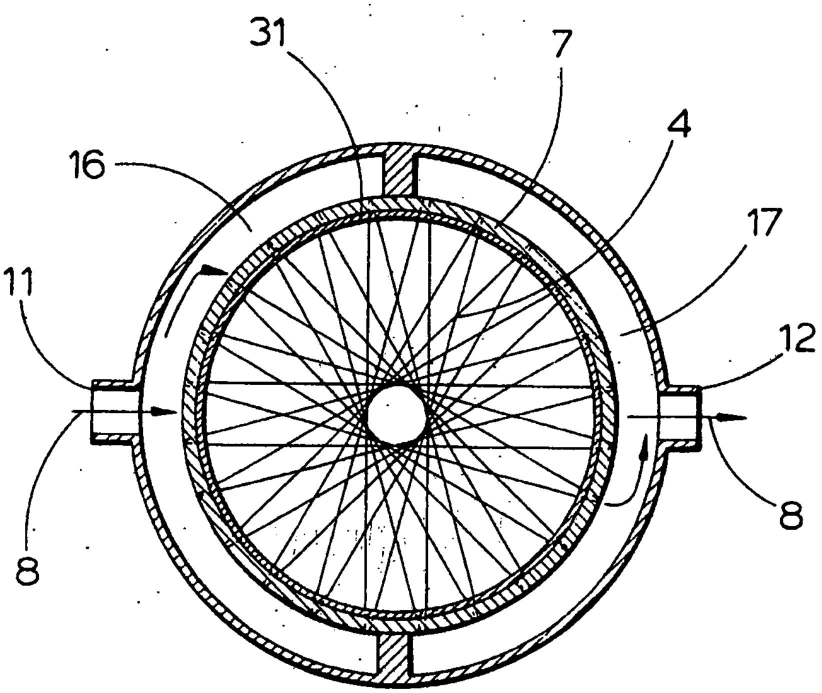

Fig . 37

SPECIFICATION

An Apparatus in Which Heat is Transferred Through Hollow Threads as Well as Hollow Threads Suitable for This Purpose

The invention relates to an apparatus in which heat is transferred through hollow threads, as well as hollow threads suitable for this purpose.

Heat exchangers composed of hollow threads or hollow fibres are known, in which the hollow threads or hollow fibres are arranged in straight lines parallel to each other and at distances from each other.

Porous hollow threads and the production thereof have already been proposed. Their use as filters, membrane carriers for separation purposes, substrate carriers or oxygenators has also been proposed.

In the already proposed method, polymers can be shaped in a simple manner into an extrudible spinning composition and this spinning composition can simultaneously be extruded and solidified without complicated spinning techniques and spinning baths having to be employed. Moreover, this method allows threads having adjustable porosity, perviousness and permeability to be obtained merely by varying the operation parameters. The porous hollow threads produced by this method are distinguished from the known threads by a favourable open surface, whereby both the outer and the inner wall of the hollow thread has a structure which is provided with open pores but is nevertheless even. The porous hollow threads already proposed can therefore be used in the textile and commerical fields, as well as in the medical field, for example, in separation processes and are particularly suitable as filters, microfilters, membrane carriers and as support substrate for certain substances.

With the method already proposed for producing porous hollow threads, a homogeneous mixture of at least two components, one component being a fusible polymer and the other component a liquid which is inert toward the polymer, both components forming a binary system which has a range of complete miscibility in the liquid state of matter and a range with mixing gaps, is extruded at a temperature above the disintegration temperatures into a bath containing the inert liquid of the extruded component mixture and having a temperature below the disintegration temperature, and the hollow thread structure formed solidifies.

With this method, the hollow fibre structure formed, once it has solidified, can be washed out using a solvent, in particular acetone, and/or an optionally heated air gap can be maintained between the outlet face of the extrusion tool and the surface of the bath and/or the homogeneous mixture can be extruded directly into the bath and/or a temperature-staggered bath can be used which can consist of one or more parts having a temperature gradient such that the temperature decreases continuously from the beginning to the outlet end of the spinning bath and/or two or more separate baths can be used which each have a different temperature, and/or the bath can be at a temperature which is at least 100°C lower than the disintegration temperature of the binary composition use, and/or the homogeneous mixture can also be extruded initially into a spinning tube proceding the bath and filled with bath fluid and/or homogeneous mixtures of from 10 to 90% by weight of polymer and from 90 to 10% by weight of inert liquid can be extruded, and/or polypropylene is used as polymer and NN-bis-(2-hydroxyethyl)-hexadecylamine can be used as inert liquid and/or the two components, namely the molten polymer and the inert liquid, can preferably be mixed continuously prior to extrusion, whereby it is desirable for mixing to take place immediately before extrusion, and/or the mixture can be further homogenized prior to extrusion, a pin mixer being particularly suitable for mixing purposes.

In order to carry out the method and to produce the porous hollow threads already proposed, it is possible to use conventional per se, in particular fibre-forming micro-molecular substances, particularly synthetic polymers which are obtained, for example, by polymerisation, polyaddition or polycondensation, a condition being that the polymer be fusible, i.e. can pass into the liquid state of matter without disintegrating and forms with a liquid which is inert toward it a binary system which has a range of complete miscibility in the liquid state of matter and also still has a range with mixing gaps in the liquid state of matter.

In order to carry out the method already proposed, it is not absolutely essential for the two components each still to have considerable solubility relative to the other component in the two-phase range. Marginal solubility in the liquid two-phase range is sufficient in many cases. However, it is important for the two components still to form two liquid phases next to each other in the liquid state. In this respect, the systems which, as already mentioned, can be used differ from those systems in which the dissolved polymer precipitates directly as a solid substance when the temperature is lowered without firstly passing through the liquid state during cooling.

As already proposed, conventional fusible polymers can be used such as the polymers, polyethylene, polypropylene, polyvinyl chloride, polyacrylates, polycaprolactam as well as corresponding copolymers and other obtainable by polymerisation; polycondensation polymers such as polyethylene terephthalate, polybutylene terephthalate, polyamide-6,6, polyphenylene oxide and polyaddition polymer such as polyurethanes and polyureas.

Suitable inert liquids basically include, as proposed, all those liquids which form a binary system of the above-mentioned type with the polymer in the liquid state, inert toward the polymer means, in this context, that the liquid does not effect noticeable decomposition of the

polymer or react with the polymer itself within a short period of time.

Although the phase diagram of the aniline/hexane system mentioned in the description of the proposed method shows the ratios for a binary mixture consisting in and for itself of only two essentially pure uniform substances, the term binary system, as mentioned therein, should not strictly apply to mixtures of solely two pure uniform substances. The average skilled man knows that a polymer is composed of a plurality of molecules of differing molecular weight distribution as described therein should be considered as *one* component, and the same applies to mixed polymers. Under certain circumstances, polymer mixtures can even behave like a uniform component, form a single-phase mixture with an inert solvent and separate into two liquid phases below the critical temperature. However preferably only one polymer is used.

In addition, the liquid need not necessarily be completely pure and represent a completely uniform substance. Thus, it is often immaterial if relatively small quantities of impurities and optionally also proportions of homologous compounds as caused by mass-production, are added.

In order to put the method already proposed into practise, a homogeneous mixture is produced from the two components at the necessary temperatures. This can be effected by mixing the inert liquid with the comminuted polymer and heating it to suitable temperatures, thus ensuring suitable thorough mixing.

In another suitable method, the two components are brought to the required temperature separately and the two components mixed together continuously in the desired proportion just prior to extrusion. This mixing process can take place in a pin mixer which is preferably arranged between the metering pumps for the individual components and the spinning pump. Subsequent homogenization may be advisable. Moreover, it is often advisable to aerate the homogeneous mixture by applying a suitable vacuum prior to extrusion.

The ratio of polymer to inert liquid in the spinning composition can be varied within wide limits. The pore volume in the interior and also the surface structure as well as the number of open pores on the surfaces of the hollow thread obtained can be controlled to a large extend by adjusting the ratio of polymer to inert liquid. Suitable hollow threads can be obtained in this way for a wide variety of uses.

It is generally sufficient for the temperature of the homogeneous mixture prior to extrusion to lie only a few degrees above the critical temperature or above the disintegration temperature depending on the respective composition.

By increasing the difference between the temperature of the homogeneous mixture to be extruded and the disintegration temperature, however, interesting effects can be achieved in the structure of the threads obtained.

The homogeneous spinning composition is then extruded into a bath containing the inert liquid of the extruded component mixture and having a temperature below the disintegration temperature. The bath preferably consists completely or mainly of the inert liquid which is also present in the extruded mixture. The temperature of the bath lies below the mixing temperatures of the binary mixture used, i.e. below the temperature above which the two components can be mixed together completely homogenously. The temperature of the bath preferably lies at least 100°C below the disintegration temperature of the mixture used.

The temperature can also be sufficiently low to move in the range in which a solid phase occurs depending on the phase diagram applying to the binary system.

If the temperature of the bath is so high that the liquid two-phases range prevails, it is necessary to solidify the resultant thread structure, as soon as possible and this can be done by suitably reducing the temperature after a certain period within the bath. It is important for the extruded mixture still to be single-phased before it enters the bath, i.e. for substantially no disintegration into two phases have yet occurred.

In certain cases, it has proven advantageous that the bath be preceded by a spinning tube which is also filled with the bath liquid and which is immersed in the spinning bath. The spinning tube can have a conventional spinning hopper at its inlet end and can be curved at its lower end in order to make it easier to take off the thread through the bath.

The spinning tube can be filled by means of a levelling vessel surrounding the spinning tube by overflow into the spinning tube. To completely fill and maintain the level in the spinning tube, it is necessary to supply to this levelling vessel more bath liquid from the main reservior than flows through the spinning tube. The excess quantity of bath liquid can be recirculated into the main reservoir through a second overflow on the levelling vessel. The main reservoir and levelling vessel can be thermostatically controlled.

Once the thread has passed out of the spinning bath, it can be washed out with a suitable extractant. A number of solvents such as, for example, acetone, cyclohexane, ethanol etc., as well as mixtures of these liquids are suitable for extraction purposes.

In some cases, it is not necessary to wash out the thread, particularly if the inert liquid used itself imparts additional properties to the thread which are intended for its subsequent use or is to fulfil a function itself. Thus, for example, liquids which exert an antistatic effect on the thread or act as lubricants can be used.

It has proven beneficial for a number of applications to maintain an air gap between the outlet face of the extrusion tool, i.e. the outlet face of, for example, a corresponding hollow thread nozzle and the surface of the bath. The structure

of the hollow thread obtained, in particular its surface, can be influenced by varying the air gap.

It has been found that the number of open pores in the surface can be reduced by lengthening the air gap and increased by shortening it. The diameter of the pores also decreases as the air gap increases.

The air gap can be heated, preferably to a temperature above the disintegration temperature of the extruded mixture.

The air gap is generally at least 1 mm wide and can assume a length of up to about 10 cm, depending on the operating conditions. It is important for no, or at least no significant, disintegration into two liquid phases to occur in the air gap before entry into the bath and, as mentioned, this can be controlled by the shortness of the path or by heating. It is however possible to counteract premature disintegration by increasing the outlet speed at the nozzle.

In a particular embodiment of the method already proposed, however, the homogeneous mixture is extruded directly into the bath, open pores having a maximum diameter being formed on the surface.

The hollow threads obtained can be used particularly well as filters. In particular, they can be used during microfiltration. The threads are particularly suitable in the medical sphere, where they can for example be used in the filtration of blood, for example for separating blood, lamella, because of their selectivity in separating bacteria. They are also very suitable as oxygenators, where oxygen flows through the interior of the hollow threads while the exterior is surrounded by blood.

The hollow threads can also be used as membrane carriers for a number of purposes. Due to their excellent even surface structure with open pores, they can in fact be coated extremely well with a firmly adhering thin layer of a material acting as membrane this frequency being effected by coating or spraying with suitable film-forming solutions. In fact, due to its excellent surface properties, not only does the resultant membrane layer adhere very well to the hollow threads, but the coating solution can be applied very uniformly as a thin skin without the solution penetrating or even dropping into the interior of the hollow thread, so very effective membranes can be produced for a wide variety of applications.

As a result of their particular surface structure and the structure inside the hollow threads, they are also eminently suitable as substrate for certain substances. Thus, the threads can be impregnated with antistatic agents which are used as inert liquid during the spinning process, or the agent can be introduced into the thread structure later on after production of the thread by treatment for example by impregnation. It is also possible to introduce the active substance into the internal continuous cavity of the thread.

In this way, compositions having a long term effect can be obtained, which slowly give up the absorbed active ingredient. Conversely, the hollow threads can also be used for adsorbing materials.

The proposed hollow threads are available in a wide range of dimensions. Thus, external diameters of up to several millimetres can be achieved. The wall thicknesses are equally widely variable and can lie, for example, between 20 microns and about 1 to 2 mm.

The pores in the proposed hollow threads can have a wide variety of shapes. Thus, they can be roundish or oblong and communicate with each other, at times through small connecting cavities and at other times by passing directly into each other. Even with hollow threads obtained from mixtures containing only about 30% of polymers the polymer can still be the matrix in which the individual pores are distributed and form more or less discrete but interconnecting cavities. Conversely, structures can also be formed in which the hollow cavities form the matrix in a similar manner to non-woven fabrics and the polymer substance is arranged in an almost fibrillar manner. The transitions between these two structures are flowing and are sometimes diffused. The structural shapes can also be influenced by other operating parameters such as take off speed, cooling speed or drafting beneath the nozzle.

The proposed hollow threads are also distinguished in particular by high permeability toward gases such as nitrogen or air. The permeability can be indicated by the so-called permeability coefficient K, as discussed in more detail in the book Flow of Fluids through Porous Materials by R. E. Collins, published by Reinhold Publishing Corp., New York, 1961 on page 10. K is defined as

$$K=\frac{Q.\eta}{A(\Delta P/h)}$$

volumetric rate of flow per a unit time (for example m³/s), n represents the viscosity of the flowing medium (Pa.s), A represents the average area through which the gas issues, P represents the pressure difference (Pa) and h represents the wall thickness of the threads.

The permeability coefficient of the hollow threads amounts to at least 10.10^{-12} cm² preferably at least 22.10^{-12} cm². Values above 100.10^{-12} cm² can be attained.

The coefficient is measured in the following manner:

several 31 cm long hollow threads are embedded at their two ends in two 5 cm long PVC tubes with the aid of a curable polyurethane compositions. Once the polyurethane has cured, a PVC tube is cut and the exposed openings are joined to a nitrogen bottle by means of a feed pipe and the end of the other tube is sealed tight by a stopper. The air issuing through the threads is measured with the aid of flow meter.

With the proposed hollow threads which have been produced from a mixture of 30% by weight of polypropylene and 70% by weight of NN-bis-

(2-hydroxyethyl)-hexadecylamine while maintaining an air gap between the nozzle and bath., the following values could be found:

K (10^{-12} cm^2)	Air Gap (mm)
99	3
22	20

The hollow threads can also be used in insulator and textile applications.

A suitable apparatus for producing the proposed hollow threads is a thermostatically controllable container, from which the inert liquid is metered into a mixer by means of a double piston pump and a second heater. A first heater is used for preminary heating Polypropylene passes from a chip container via an extruder and a first gear pump into the mixer, from which a hollow thread nozzle is fed via a second gear pump and supplied with the necessary quantity of nitrogen via a Rotameter. The issuing mass passes via an air gap into a spinning tube which is provided with a spinning hopper and is supplied with inert liquid from a main reservoir via a levelling vessel. The spinning tube has a bend at its lower end and the threads are wound after leaving the bath.

The following embodiment of the method already proposed has also been recommended;

Some polypropylene having a melting index of 1.5 g/10 min. is melted in an extruder at a heating temperature of from 260 to 280°C and is metered via a gear pump into a very effective pin mixer.

Some NN-bis-(hydroxyethyl)hexadecyl amine is simultaneously preheated to 135°C in a passage heater by means of a double piston pump and metered via a separate pipe also into the mixer.

The mixing ratio of polypropylene:amine is 30.70. The mixer speed is adjusted to 400 rpm.

After passing through the mixer, the two substances which have become homogeneous are extruded through a gear pump in a quantity of 15 g/min into a hollow thread nozzle having an internal diameter of 2000 μm and a free annular gap of 400 μm. The hollow thread is formed by adding 4 l/h of nitrogen into the gas capilliary of the nozzle.

The issuing molten thread plunges after a free fall of 3 mm into the spinning funnel filled with amine acting as precipitation bath, flows with the precipitant through the subsequent spinning tube having a diameter of 8 mm and the length of 400 mm and is wound on a winding unit after passing at 7 m/min through a subsequent spinning bath which is 1 m long. The hollow thread obtained is extracted with alcohol and freed from amine. The hollow thread has an external diameter of 2200 μm and an internal diameter of 1400 μm.

A cavity-forming fluid, in particular a pore-forming liquid or a gas can be blown into the hollow thread during the spinning of the hollow thread to produce stable hollow threads having large external diamensions and very small wall thickness.

It has now surprisingly been found that the already proposed porous hollow threads or fibres are also particularly well suited, in addition to the already mentioned applications, to the transfer of heat, particularly if they have properties and/or a shape which increase their thermal conductivity and/or their heat transmission and/or their heat transfer and if they are arranged, utilising their flexibility, in such a way that the apparatuses produced from porous hollow threads of this type have a greater resistance to external mechanical stresses so that they guarantee and undiminished heat transfer capacity even after prolonged operation.

In the case of a liquid which is to be cooled and which is flowing through the porous hollow threads, it is particularly advantageous if, in addition to the heat transfer through thermal conductivity taking place through the non-porous portions of the hollow thread wall, a proportion of the liquid flowing through the porous hollow threads flows outwards through the pores and evaporates there, i.e. on the external surface of the porous hollow threads, so that the necessary vaporisation energy is removed from the proportion of the liquid remaining in the interior of the hollow thread and is thus cooled.

An object of the present invention is to improve the known heat exchangers composed of hollow threads with respect to their heat transfer capacity as well as their serviceability and to provide an apparatus in which heat is transferred which, with regard both to its production and its serviceability and heat transfer capacity, does not have the disadvantages of conventional heat exchangers produced from the known hollow threads and which can be produced in a simple and rapid manner.

According to the invention, there is provided an apparatus for transferring heat comprising hollow threads composed of synthetic polymers having 10 to 90% by volume of inter-communicating pores and an even surface containing open pores, the proportion of the surface which is open amounting to from 10 to 90%.

According to a second aspect of the invention there is also provided a hollow thread composed of synthetic polymers containing from 10 to 90% by volume of inter-communicating pores and an even surface having open pores, the proportion of the openings in the surface amounting to from 10 to 90%, wherein a layer which acts as a membrane is applied to the hollow threads and/or the hollow threads contain graphite, metal particles, fillers, stabilisers, additives, carbon black or dye pigments or any combination thereof, and/or the hollow threads have a substantially circular cross-section with an external diameter falling within the range of 0.1 to 4 mm and/or the hollow threads have a wall thickness falling in the range of from 20 to 500 μm and/or the hollow threads are internally and/or externally profiled and/or the hollow threads have a cross section which changes continuously or intermittently, in shape and/or size in its longitudinal direction

and/or the hollow threads consist of two or more components and/or in that only a proportion of the components is porous.

On the one hand the flexibility of the porous hollow threads is utilised by means of the design of the apparatus according to the invention and, on the other hand, the special design of the already proposed porous hollow threads results in an increase in thermal conductivity and/or heat transmission.

In a particularly preferred embodiment of the apparatus according to the invention, each individual porous hollow thread is arranged over the majority of its length, preferably over its entire length and/or the majority of all porous hollow threads, preferably the entirety of all porous hollow threads is arranged in the form of regular and/or irregular loops.

Apparatus of the type according to the invention, in which heat is transferred, do not have the disadvantages of the known heat exchanges composed of hollow threads in which the hollow threads are arranged in straight lines, parallel to each other and at distances from each other. In fact, this known type of arrangement, which is also conventional in metal tubular heat exchangers, make the production of such heat exchangers from hollow threads difficult and expensive. In addition, with this known arrangement of the hollow threads, the bundles of hollow threads can be damaged, for example nicked, even by minor external mechanical influences.

In order to increase the heat transfer capacity of an apparatus according to the invention, it is particularly advantageous if the porous hollow threads used contain good heat conducting materials such as, for example metals, and graphite in dust or powder form, whereby these materials can be contained in the polymers forming the hollow threads and/or can be inserted into the pores. The porous hollow threads can however also contain, in addition for example, fillers, stabilisers, additives, carbon black, dye pigments or the like. The external diameter of the hollow threads used for the apparatus according to the invention preferably lies in the range of from 0.1 to 4 mm. Moreover, the apparatus according to the invention can contain hollow threads produced from two or more components, of which possibly only a proportion is porous.

When using porous hollow threads with a small wall thickness, the apparatuses according to the invention which are obtained have a large heat exchange capacity.

Porous hollow threads having a, for example, eliptical or triangular, rectangular, pentagonal, hexagonal and polygonal cross-section are suitable for the production of a heat exchanger according to the invention, particularly those having a round cross-section since, in apparatuses with crossing porous hollow threads according to the invention produced from porous hollow threads having a round cross-section, the threads contact each other substantially only at points and, thus, only a minute proportion of the entire heat exchanger area is lost through these points of contact.

The porous hollow threads used can also advantageously be profiled internally and/or externally. It is also possible to firmly join together two, three or more porous hollow threads lying in a parallel position relative to each other, at their respective contacting surfaces, for example by fusion, welding or adhesion. Porous hollow threads having a cross-section which optionally changes periodically in shape and/or size continuously or intermittently in their longitudinal direction are also suitable. Porous hollow threads of this type can advantageously influence the mode of operation of the heat exchanger according to the invention in various ways. Thus, by means of porous hollow threads which are suitably profiled internally and/or externally it is possible, for example, to increase the internal and/or external heat exchange surface, to improve the nick-resistance of the porous hollow threads and/or to reduce the contact area of the crossing porous hollow threads. Moreover, the heat transfer capacity is further increased since the heat transmission on the profiled surfaces of the porous hollow threads is improved by turbulence in the respective fluid. Apparatuses which are more compact and/or more stable in shape can also be produced in part from porous hollow threads of a non-circular cylindrical shape.

To ensure good conduction of heat through the porous hollow threads, the wall thereof should be as thin as possible but should still be sufficiently thick to meet the mechanical requirements. Porous hollow threads whose wall thickness ranges from 0.02 to 0.5 μm have proven advantageous for most purposes. To achieve a good heat transmission coefficient (k-number), the cross-sections of the porous hollow threads used should be dimensioned accordingly.

The looped or partially looped arrangement of the porous hollow threads in an apparatus according to the invention is achieved according to the invention in a simple manner particularly in that one or more continuous porous hollow threads are wound using a spooling or winding device with one or more thread guides which are moved to and fro parallel to the rotational axis of the spooling device, for example, on a perforated tubular reel holder (also known as bobbin or spool) and, in this way, form a single or multiple layered spooled or wound member.

This arrangement is particularly advantageous since, in the serviceable condition of the apparatus, the porous hollow threads have the shape of a spatially extending coil, the porous hollow threads advantageously being arranged in several layers for achieving an easily penetrable bobbin package which is stable in shape in such a way that the porous hollow threads in each layer contact the porous hollow threads of the adjacent layers and cross over optionally several times. This arrangement of the porous hollow threads allows a large heat transfer surface in a small

space since, although the porous hollow threads touch each other at the points of intersection, only an insignificant proportion of the heat transfer surface is lost by this reciprocal contact.

The reel holder accommodating the spooled or wound member need not necessarily have a circular cross-section as its cross-section can also be designed elliptical or as a polygon, in particular as a rectangle with rounded corners. Similarly, the reel holder used for producing the spooled or wound member can also have a cross-section which increases or decreases along its longitudinal axis. Thus, its surface area can be designed, for example, conical, diabolo-shaped, truncated pyramid shaped with rounded lateral edges or barrel-shaped etc. so that the porous hollow threads wound on a reel holder shaped in this way generally form a spooled or wound member whose shape corresponds to the shape of the respective reel holder.

In another embodiment of the apparatus according to the invention, the porous hollow threads have the shape of a spiral lying in one plane.

The apparatuses according to the invention can however also be produced from one or more sheets which have been produced by a weaving, knitting or working method or a depositing method. Like the spooled or wound members, sheets of this type can also be produced in a rapid and simple manner.

In order to produce apparatuses according to the invention from spooled or wound members, the two face ends can be cast on a short portion, measured in the longitudinal direction of the wound member, for example in a curable casting composition such as cast resin, polyurethane or the like, the casting composition penetrating completely in the said region of the wound member and optionally forming one flange-like projection outside each wound member, having a larger circumference than the wound member. A (flange-like) projection of this type can however also be provided only on one of the two faces of the wound member. The arc-shaped turned back parts of the individual layers of the wound member lying at the ends of the wound member are removed by carrying off a proportion of each of these (flange-shaped) projections from the end into the region of the porous hollow threads, and a configuration is produced in this way from the original wound members which consists of a plurality of hollow threads pieces arranged in several layers in the form of a coil and crossing each other several times, whose openings, merge from the casting composition at the external faces, generally running perpendicularly to the longitudinal axis of the wound member, of the remaining part of each of the (flange-like) projections described above.

To produce apparatuses according to the invention from sheets, one or more edges of the sheets which are optionally also superimposed can be cast in a suitable manner, for example in cast resin in each case and the openings of the porous hollow threads can then be freed in a similar manner, as already described above for spooled and wound members.

By winding, shifting or arranging the porous hollow threads in another manner and by cutting the bundle of windings in a suitable manner it is possible to produce apparatuses according to the invention in which the inlet openings and the outlet openings of the porous hollow threads lie in one and the same plane, but are shifted, for example, by 180° each and/or at equal or differing distances from each other in each case and are thus arranged in such a way that all inlet openings lie in one half of this plane and all outlet openings lie in the other half of this plane.

It is also possible to produce apparatuses according to the invention which allow as much fluid as desired to participate in the heat transfer without the individual fluids being mixed together.

The apparatuses according to the invention produced from a spooled or wound member can, for example, be equipped in such a way that the inlet openings and the outlet openings for a first fluid lie at one end of the apparatuses and those for a second fluid lie at the other end of the apparatuses.

To produce a plurality of smaller apparatuses, it is possible to divide the spooled or wound members or sheets intended for the production of the apparatuses into units, for example, strips or discs of desired size, in which case the porous hollow threads are preferably fixed in shape and position beforehand in a suitable manner, for example, by casting into cast resin or the like as already described, in those regions in which the division is to take place, and their openings can thus be freed without difficulty by the division.

It is also possible within the scope of the present invention to cast the porous hollow threads into a material which is a good conductor of heat in order to transfer heat in this manner from one fluid to the said material which is a good conductor of heat or vice versa. The apparatuses according to the invention which are designed in this way and which also have, for example, two separate circuits for two fluids which are to be kept apart allow heat to be transferred, for example, from the first fluid initially onto the cast member which is a good conductor of heat and thence to deliver it to the second fluid. It is also possible with apparatuses of this type, for example, to deliver the heat absorbed, for example, by radiation, from the cast member which is a good conductor of heat simultaneously to two fluids.

Apparatuses according to the invention are suitable for solving even the most demanding problems of heat transfer of the type which can arise, for example during evaporation or condensation. In particular, the apparatuses according to the invention are suitable wherever there are only relatively small temperature differences for the recovery of energy which inevitably demand large heat transfer surfaces which obviously have to be arranged in the

minimum of space. Due to the desirable corrosion properties of the porous hollow threads which can be used for the production of the heat exchanger according to the invention, the apparatuses according to the invention are particularly suitable for corrosive media such as for example acids and caustic solutions. By selecting suitable porous hollow threads to be used, it is possible, by means of the known differing surface properties thereof, also to use the apparatuses according to the invention for those fluids which tend to form deposits on the tube walls in conventional metal tubular heat exchangers.

The apparatuses according to the invention are therefore equally suitable for chemical processes, in the production or conversion of energy, in refrigeration, in air-conditioning, in the food industry, in central heating, in land, water and air vehicles, in particular as an oil cooler, as a water cooler for discharging engine heat or for heating fresh air supplied to the interior of the vehicle, as a condenser and as an evaporator, in particular also as a flash evaporator. The apparatuses, according to the invention are suitable quite specifically for heat pump devices in which, for example, heat from the surrounding air or from the ground is used for heating housing space or as collectors for receiving the heat of the sun, for which purpose those embodiments of the apparatuses according to the invention in which the porous hollow threads are arranged in only one layer and, more over, are black, have proven particularly advantageous.

The apparatuses according to the invention are thus suitable for solving most problems of heat transfer with optionally simultaneous exchange of material, i.e. for the heat transfer from gaseous fluids to gaseous fluids, from liquid fluids to liquid fluids, from liquid fluids to gaseous fluids and vice versa, from solids materials to gaseous and/or liquid fluids and vice versa, in which case care has to be taken to limit the temperatures of the materials participating in the heat exchange accordingly due to the physical and chemical properties of the porous hollow threads used.

In addition to the suitable polymers already proposed and mentioned, the polyamides, in particular polyhexamethylene adipic acid amide, the polyesters as well as the polyolefins can also use in embodiment of the invention.

Due to their chemical resistances, for example, to food stuffs and carbon dioxide-containing liquids, polyesters, in particular polyethylene terephthalate, are preferred. If chemical resistance is desired in addition to good thermal stability, hollow threads composed of polyolefins, in particular of polypropylene, are preferred. If higher strength values are desired, the hollow threads are produced from polyamides, in particular from polyhexamethylene adipic acid amide.

When dimensioning the apparatuses according to the invention, it should be noted that the heat transfer surface attainable per unit volume available is greater, the smaller the diameter of the porous hollow threads to be used. The amount of heat to be transferred generally increases as the diameter of the hollow threads decreases if the cross-section of flow of all porous hollow threads and the quantity of fluid remain constant. It should however be noted that the pressure loss in the porous hollow threads also increases in this case. It should also be noted that the nick-resistance of the porous hollow threads generally decreases as the diameter increases and the wall thickness stays constant. With a suitable choice and dimensioning of the porous hollow threads used for the apparatuses according to the invention, it is possible to achieve specific heat transfer capacities which can be better, and in part even considerably better than those which can be achieved with conventional metal tubular heat exchangers. The choice of suitable porous hollow threads should be made as far as possible in such a way that the heat transmission resistance through the wall of the porous hollow threads is substantially negligible relative to the heat transfer resistances occurring inside and outside the porous hollow threads. This means that porous hollow threads made of a material having relatively good properties of thermal conductivity should have thicker walls than those with very low thermal conductivity values.

A "hollow thread" in the context of the present invention is a hollow cylindrical configuration of any length having a, for example, circular or elliptical cross-section with a wall thickness which is generally substantially constant in the longitudinal and circumferential direction.

The term "cross-section" of the porous hollow threads the spooled or wound member or the reel holder is interpreted in the context of the invention as the cross-sectional area obtained if a porous hollow thread, a spooled or wound body or a reel holder is cut at a random point or at a point described in more detail, perpendicularly to its longitudinal or rotational axis. In the case of a round porous hollow thread, a circular cross-section is obtained in this way. In the case, for example, of a spooled or wound member which is wound on a reel holder having a rectangular cross-section with rounded corners, a rectangular annular cross-section with rounded corners is obtained according to this definition.

The term "loop form" in the context of the present invention is interpreted as that form which differs from a rectilinear form and, in particular, that type of flat or three-dimensional curvature in which the radius of curvature is sufficiently large to prevent nicking of the porous hollow threads. The radius of curvature is generally smaller than 1 m but it can also be larger. It the object forming the basis of the present invention, it is not necessary for all porous hollow threads to have a loop form over their entire length, but rather it is sufficient for the majority of the porous hollow threads to have a loop form i.e. for each individual porous hollow thread in an apparatus according to the invention to have a loop form over a majority of its length

and/or for rectilinear and loop-form porous hollow threads to be present providing the total length of all the porous hollow threads and/or hollow thread portion present in loop form is greater than the total length of all rectilinear porous hollow threads and/or hollow thread portions.

This loop form of the porous hollow threads allows the porous hollow threads to cross over, optionally several times at substantially short intervals, and to support each other in this way so that each porous hollow thread is generally unsupported only over relatively short portions of its length so that the risk of the porous hollow threads being nicked is reduced considerably.

Although the above-mentioned advantages are generally obtained only by the arrangement according to the invention of the porous hollow threads in apparatuses in which heat is transferred, it is nonetheless basically possible also to arrange the porous hollow threads in a known manner, thus, for example, in a U-shape or in the form of a bundle of straight porous hollow threads and the like arranged parallel to each other and at distances from each other.

Serviceable apparatuses which possibly yield satisfactory to advantageous results can also be produced using porous hollow threads other than those according to the second aspect of the invention and those already proposed.

Finally, it is possible according to the invention and in many cases advantageous to use those porous hollow threads for the production of apparatuses according to the invention in which, in addition to the heat transfer and/or the vaporisation of a proportion of the liquid flowing through the porous hollow threads on the external surface of the porous hollow threads, filtration, microfiltration, transfer of material or exchange of material takes place as proposed. Those porous hollow threads which contain no layer acting as a membrane which is optionally impermeable to fluid and thus have an open pored surface, are generally particularly suitable for this purpose.

Moreover, it is advantageous in many cases for these, but also other, applications to use those hollow threads which have an open pored surface only in portions and have the membrane-like layer described in more detail above on the remaining portions. The optionally uninterrupted membrane-like layer can be arranged on the external and/or internal surface of the porous hollow threads. This layer is particularly preferably provided after production of the spooled or wound member, in particular inside the porous hollow threads.

Finally, it is possible according to the invention also to use the apparatuses according to the invention with heat exchangers of the type which frequently occur during, for example, mixing dissolution, dilution or chemical reaction, etc., of several reactants, a proportion of a fluid reactant flowing through the hollow threads being allowed to issue through the pores of the hollow threads and enter a second fluid reactant, for example.

As the porous hollow threads described herein have proven most suitable not only in the apparatus according to the invention, the scope of the invention also covers the porous hollow threads proposed, the hollow threads comprising the properties according to the invention individually or in any combination.

The invention will now be described in more detail with reference to the drawings.

Figures 1 to 7 show cross-sections through porous hollow threads of various shapes.

Figures 8 and 9 show longitudinal sections through porous hollow threads which are not designed as circular cylinders.

Figures 10 and 11 show a simplified schematic view of the production of a multi-layer wound member from a porous hollow thread.

Figure 12 shows a simplified schematic view of a longitudinal section through a spooled member of porous hollow threads with flange-like projections at its ends cast from a casting composition.

Figures 13 to 15 show a simplified schematic view of longitudinal sections through spooled members of various shapes composed of porous hollow threads with flange-like projections cast at their ends from a casting composition.

Figure 16 shows a simplified view of a spooled member from porous hollow threads with only one flange-like projection made of a casting composition arranged at its end.

Figure 17 shows a simplified schematic view of a spooled member with flange-like projections cast at both its ends from a casting composition.

Figures 18 to 21 show a simplified schematic view of embodiments of apparatuses according to the invention using a spooled member made of porous hollow threads.

Figures 22 to 24 show a simplified schematic view of the production of a spooled member made of two porous hollow threads.

Figure 25 shows a simplified schematic view of an embodiment of an apparatus according to the invention using a spooled member produced according to Figures 22 to 24.

Figures 26 to 31 show a simplified schematic view of various embodiments of bundles of hollow threads produced from spooled members each having differing cross-sectional shapes.

Figures 32 to 37 show a simplified schematic view of the production of an embodiment of the apparatuses according to the invention from a substantially disc-shaped wound member from porous hollow threads.

Figures 1 to 5 show possible cross-sections of profiled porous hollow threads of the type which are suitable for apparatuses according to the invention.

In the form illustrated in Figure 1, the porous hollow thread has a substantially circular cylindrical cavity 27 while it has a rib-like elevation 26 running in its longitudinal direction on its exterior, which can optionally consist of a different material from the hollow thread sheath.

The porous hollow thread illustrated in Figure 2 also has a substantially circular cylindrical cavity 27 and four rib-like elevations 26 running in its

longitudinal direction, optionally made of a differing material.

The porous hollow thread illustrated in Figure 3 has a substantially three-tabbed cross-section, the cavity 27 having a similar shape to the hollow thread sheath 28 so that this porous hollow thread has a wall of substantially constant thickness over its circumference.

The porous hollow thread illustrated in Figure 4 has an externally substantially circular sheath 29 which has on its interior four rib-like elevations 26 running in the longitudinal direction of the porous hollow thread and penetrating into its cavity 27 which are optionally made of a differing material from the sheath 29.

Figure 5 shows a porous hollow thread in which the sheath 28 has a hexagonal annular cross-section and the cavity 27 has a hexagonal cross-section.

Figure 6 shows a cross-section through a hollow thread configuration which can be produced, for example, by fusing three porous hollow threads of round cross-section together on their common lines of contact.

Figure 7 shows a cross-section through a porous hollow thread with a cross member 29 arranged centrally inside the porous hollow thread and running in its longitudinal direction. This porous hollow thread therefore has two equally large cavities 27 which are separated from each other by the cross member 29 and run parallel to each other and have a semi-circular cross-section.

Figure 8 shows a longitudinal section through a porous hollow thread having an external diameter or circumference which increases and then decreases again at optionally regular intervals in its longitudinal direction and having an internal diameter or cavity circumference which decreases and then increases again at optionally regular intervals in its longitudinal direction. The porous hollow thread thus has a sheath 28 whose wall thickness changes in the longitudinal direction of the porous hollow thread.

Figure 9 shows a longitudinal section through a porous hollow thread with a cross-section which increases at optionally regular intervals in its longitudinal direction, the wall thickness of the porous hollow thread remaining constant in its longitudinal direction.

Figures 10 and 11 show a simplified schematic view of a known device for the production of spooled members which are suitable for apparatuses according to the invention. A continuous porous hollow thread 1 supplied is wound by means of a thread guide 2 which moves to and fro onto a rotating perforated reel holder 3 so that a spooled member 4 is produced which is made up in the manner of a coil of several layers of portions of the continuously supplied and wound porous hollow thread 1 which cross over at a predetermined angle.

Figure 12 shows a longitudinal section through a spooled member 4 which is produced using for example, a device described with reference to Figures 10 and 11. The spooled member 4 is provided at its two ends 5 with flange-like projections 7 made of a curable casting composition which has been brought into the desired shape by centrifugal casting. The openings of the porous hollow threads of the spooled member 4 can be freed by severing a part of the flange-like projections 7 along the lines A and B. The perforated reel holder 3 ensures that the spooled member 4 is traversed radially.

The spooled member 4 illustrated in a longitudinal section in Figure 13 is formed by the uniform winding of a continuous porous hollow thread on a conically designed reel holder 3 and thus has a conical shape itself. With this spooled member 4, the ends of the individual tube portions are freed by severing a proportion of the flange-like projections 7 (as already described with reference to Figure 12).

The spooled member 4 illustrated in the longitudinal section in Figure 14 is produced by the uniform winding of a continuous porous hollow thread on a diabolo-shaped reel holder 3 and therefore has a diabolo shape itself. In this spooled member 4, the ends of the individual hollow thread portions are already freed by severing a part of the flange-like projections 7 (as already described with reference to Figure 12.

The spooled member 4 illustrated in the longitudinal section in Figure 15 is produced by the uniform winding of a continuous porous hollow thread onto a barrel-shaped reel holder 3 and is thus barrel-shaped itself. With this spooled member 4, the ends of the individual tube portions are freed by severing a part of the flange-like projections 7 (as already described with reference to Figure 12).

The spooled member 4 illustrated in Figure 16 is produced by the uniform winding of a continuous porous hollow thread on a circular cylindrical reel holder and thus has a circular cylindrical shape itself. This spooled member 4 is provided with a flange-like projection 7 only at one end so that the ends of the individual hollow thread portions of the spooled member 4 are freed only on this one side by the severing of part of the flange-like projection 7 already described.

The path of flow of a fluid through the porous hollow threads of a spooled member of this type runs in the manner of that of a U-shaped pipe. This means that the inlet and outlet openings for the fluid lie in one and the same plane in this spooled member.

Figure 17 shows a spooled member of the type produced when the flange-like projections 7 are partially severed, for example in the manner shown in Figure 12 along the lines A—A and B—B.

Figure 18 shows the use of a spooled member 4 produced in the manner described with reference to Figures 10 and 12 in an apparatus according to the invention. The spooled member 4 with the flange-like projections 7 is arranged in the correspondingly dimensioned housing 10 in this case. A first fluid 8 flows through the inlet nozzle 11 into the distribution chamber 16 of the

apparatus and passes thence into the inlet openings of the porous hollow threads arranged in the spooled member 4, flows through them and leaves them at the opposite end of the spooled member 4, passes into the collecting chamber 17 of the heat exchanger and leaves it through the outlet nozzle 12. It can also flow through the porous hollow threads in the opposite direction. A second fluid 9 flows through the inlet nozzle 13 into the core chamber 18 of the spooled member 4 which is sealed at its end 15, flows through the spooled member 4 in the radial direction from the interior outwards and passes into the annular cylindrical collection chamber 19, whence it leaves the apparatus through the outlet nozzle 14.

As in the embodiments of the apparatus according to the invention described in Figures 19 to 21 and 34 to 37, the first fluid 8 can be a liquid and the second fluid 9, for example, a gas or air, which absorb and entrain the liquid vapour produced on the external surface of the hollow thread portions when employing evaporation or vaporisation cooling. The first fluid 8 can have a higher or lower temperature than the second fluid 9. However, if it is undesirable for the fluids to flow through the wall of the porous hollow threads the apparatuses can be produced according to the invention from porous hollow threads surrounded by a membrane-like layer which is impermeable to fluid.

Figure 19 shows an apparatus according to the invention in which the spooled member 4 is provided with a partition wall 21 which is arranged in such a way, however, that the free cross-section of flow of the individual porous hollow threads is not interrupted by it. A first fluid 8 traverses the apparatus in the same way as described with reference to Figure 18. A second fluid 9 flows through the inler nozzle 13 of the apparatus into the annular cylindrical distribution chamber 20, then traverses the right half of the spooled member 4 in a radial direction from the exterior inwards and enters the core space 18 of the spooled member 4 which is sealed at both end faces 15. The second fluid 9 then traverses the left half of the spooled member 4 in a radial direction from the interior outwards and passes into the annular cylindrical collection chamber 19, whence it leaves the apparatus through the outlet nozzle 14.

Figure 20 shows an apparatus according to the invention in which the porous hollow threads of the spooled member 4 according to Figure 16 are provided with a flangelike projection 7 only on one side and are cut away and the inlet openings and the outlet openings of the individual porous hollow threads are each offset by 180° relative to each other, thus face each other, i.e. are arranged in a similar manner to that known from conventional heat exchangers with U-shaped pipes. With this apparatus, a first fluid 8 flows through the inlet nozzle 11 into the distribution chamber 16, passes thence into the interior of the porous hollow threads of the spooled member 4, traverses it firstly in one direction and then in the substantially opposite direction and subsequently enters the collection chamber 17 whence it leaves the apparatus again through the outlet nozzle 12. A second fluid 9 flows through the inlet nozzle 13 into the annular cylindrical distribution chamber 20, whence it flows through the spooled member 4 from the exterior inwards in a radial direction and enters the core space 18 of the spooled member 4 which is sealed at the end 15 and thence leaves the apparatus through the outlet nozzle 14.

Figure 21 shows an apparatus according to the invention which combines the essential features of the spooled member 4 shown in Figures 19 and 20. in this case, the first fluid 8 flows through the porous hollow threads of the spooled member 4 in the manner described with reference to Figure 20 and the second fluid 9 flows round the porous hollow threads of the spooled member 4 in the manner described with reference to Figure 19.

Figures 22 to 23 show a simplified schematic view of a device for the production of a spooled member 4 from two porous hollow threads 1 which are supplied separately from two spools 6 but are wound simultaneously onto a common reel holder 3. By arranging the thread guides 2 offset in the longitudinal direction of the spooled member 4 in the manner shown in Figures 23 and 24, it it possible to produce a spooled member 4 in which the respective layers of the two porous hollow threads 1 are wound offset relative to each other in the longitudinal direction of the spooled member 4 so as to form a region 22 at each of the ends of the spooled member 4 which is formed only by one of the two porous hollow threads. A spooled member which has the inlet and the outlet openings for a first fluid on one side and those for a second fluid at the opposite end is produced by removing these two regions 22.

The use of a spooled member produced in this way in accordance with Figures 22 to 24 in an apparatus according to the invention is illustrated in Figure 25. In addition, the spooled member 4 is located in a solid or liquid substance 23 which is a good conductor of heat in this embodiment illustrated in Figure 25. An apparatus of this type allows, for example, the heat to be transferred from a first fluid 8 to a second fluid 9 utilising the good heat conducting properties of the substance 23, the fluid 8 flowing through the corresponding layers of the spooled member 4 formed by a porous hollow thread, for example in the manner illustrated in Figure 20. In Figure 25, this path of flow is indicated schematically as a broken line, while the second fluid 9 follows a path of flow which is a mirror image of it, which is indicated by the continuous line in Figure 25.

Figure 26 shows a spooled member 4 with flange-like projections 7 arranged at its two ends, the flange-like projections 7 (like those of the spooled member 4 illustrated in Figures 12 to 21) having a larger external circumference than the spooled member 4. The flange-like projections 7 and the spooled member 4, however, have an

elliptical annular cross-section in this case.

Figure 27 shows that a spooled member 4 can be cast not only at its ends and cut up accordingly in the manner described above but can also be cast along one or more of its generating lines. In the embodiment illustrated in Figure 27 the porous hollow threads consequently merge into two circular cylindrical cavities 24 and 25 which are surrounded by a wall consisting, for example, of cast resin which, as explained with reference to the Figures already described, act as distribution and collection chamber for the fluid flowing through the porous hollow threads.

Figure 28 shows a cross-section through a spooled member 4 which is obtained if porous hollow threads are wound on a reel holder 3 with a rectangular cross-section having rounded corners.

Figure 29 shows a cross-section through a spooled member 4 which is obtained if a spooled member 4 according to Figure 28 is cast, for example in cast resin, along two of its generating lines in the manner described with reference to Figure 27 and the openings of the porous hollow threads are then freed in the manner already described.

Figure 30 shows a cross-section through a spooled member 4 which can also be produced from the spooled member 4 illustrated in Figure 28, and Figure 31 shows one which is obtained in a manner similar to that described in Figure 27 from a spooled member 4 of circular annular cross-section. The embodiments according to the invention illustrated in Figures 27 to 31 are eminently suitable for the heat transfer from a liquid medium to a gaseous medium (for example as a car radiator) or vice versa, the liquid medium preferably flowing through the porous hollow threads and the gaseous medium flowing round the porous hollow threads, whereby vaporization cooling can be employed or not employed, depending on the type of porous hollow threads used, as described above.

Figure 32 shows a cross-section through an annular coil holder 31 of the type which is suitable for the production of a disc-shaped coiled member from porous hollow threads.

Figure 33 shows a possible arrangement of the individual thread portions, for example of a continuously wound porous hollow thread on the annular coil holder 31. In this case, the hollow thread portions can be arranged in several superimposed layers which each cross each other several times. By casting the external portion of the annular coil holder 31 for example into a curable casting composition and then removing a part of the annular casting composition projection into the region of the turned back fragments 32 of the hollow thread portions, the porous hollow thread 1 which is initially continuous is divided into a plurality of equally long hollow thread portions arranged in several layers and crossing over each other several times and the openings in the individual hollow thread portions are freed at each severing point. The external diameter of the unworked part of the annular casting composition projection is thus generally equal to or slightly smaller than the external diameter of the annular coil holder 31.

Figure 34 shows a sectional illustration along the line XXXIV—XXXIV in Figure 33 of a disc-shaped embodiment of the apparatus according to the invention in which a wound member 4 according to Figure 33 has been used. By suitably arranging the inlet nozzle 11 and the distribution chambers 16 as well as the collection chambers 17 and the outlet nozzle 12 for a first fluid 8 and the inlet nozzle 13 and the distribution chambers 20 as well as the collection chambers 19 and the outlet nozzle 14 for a second fluid 9, an apparatus having a total of two inlets and two outlets for each of the two fluids 8 and 9 is obtained. In this case, the fluid stream entering the apparatus through the inlet at anytime is divided so that only half of each partial stream of fluids 8 and 9 reaches the two outlets communicating with the corresponding inlet at any time and combines there with one of the halves of the other partial stream of fluids 8 and 9. Figure 34 shows this path of flow by arrows and four hollow thread portions drawn as thick lines.

Figure 35 shows a cross-section along the line XXXV—XXXV through Figure 34. The annular coil holder 31, the annular projection 7 made of a curable casting composition, the wound member 4 as well as the two opposing distribution chambers 16 for the first fluid 8 can be seen.

Figure 36 shows another possible arrangement of a continuous porous hollow thread 1 on an annular coil holder 31 for the production of a hollow thread winding for disc-shaped embodiments of the apparatus according to the invention.

Figure 37 shows a cross-section through an apparatus according to the invention in which a wound member according to Figure 36 has been used. The openings in the individual hollow thread layers have been freed here, as already described with reference to Figures 32 to 35. In this embodiment, the first fluid 8 flows through the inlet nozzle 11 into the distribution chamber 16, then traverses the porous hollow threads of the wound member 4, enters the collection chamber 17 and leaves the apparatus through the outlet nozzle 12. The reference numerals of the remaining parts of this apparatus correspond to the parts described by way of example with reference to Figure 34. An exemplary second fluid participating in the heat transfer traverses the apparatus illustrated in Figure 37 in substantially the axial direction thereof.

Whereas the apparatus illustrated in Figure 37 is thus suitable for transferring heat from one medium to another, a total of three media can participate in the heat transfer in the apparatus illustrated in Figures 34 and 35. With the apparatus illustrated in Figures 34 and 35, the third medium could be, for example, a solid or liquid substance which is a good conductor of heat and which surrounds the porous hollow

threads from the outside or a third fluid which flows through the heat exchanger in its axial direction.

The use of the disc-shaped wound member described by way of example with reference to Figure 33 and 36 is not restricted to the production of substantially disc-shaped apparatuses but rather it is possible according to the invention to superimpose a plurality of these wound members and, in this way, to allow an optional number of fluids to participate in the transfer of materials and/or heat.

Claims

1. An apparatus for transferring heat comprising hollow threads composed of synthetic polymers having from 10 to 90% by volume of inter-communicating pores and an even surface containing open pores, the proportion of the surface which is open amounting to from 10 to 90%.

2. An apparatus according to Claim 1, wherein a majority of the individual hollow threads are arranged in the form of regular and/or irregular loops over a majority of their respective lengths.

3. An apparatus according to 1 or 2 wherein all of the hollow threads are arranged in the form of regular and/or irregular loops over their respective lengths.

4. An apparatus according to any preceding Claims, wherein the hollow threads are arranged in the form of regular and/or irregular loops over the entirety of their respective lengths.

5. An apparatus according to any preceding Claims, wherein the hollow threads arranged in the form of a spatially extending coil and/or a spiral lying in one plane.

6. An apparatus according to any preceding claims, wherein the hollow threads are arranged in several layers.

7. An apparatus according to Claim 6, wherein the hollow threads in each layer cross over the hollow threads in each of the adjacent layers several times.

8. An apparatus according to any preceding claims, comprising a multi-layer spooled or wound member.

9. An apparatus according to any preceding claims, comprising a spooled or wound member having a round, elliptical or polygonal annular cross-section with rounded corners.

10. An apparatus according to any preceding Claims, comprising a spooled or wound member having a rectangular annular cross-section with rounded corners.

11. An apparatus according to any preceding claims, comprising a spooled or wound member with an annular cross-section which increases and/or decreases along its longitudinal axis.

12. An apparatus according to any preceding claims, comprising a woven, worked or knitted sheet or a sheet produced by a depositing method.

13. An apparatus according to any preceding claims, further comprising at least one inlet each and at least one outlet each for at least three fluids participating in the heat transfer.

14. An apparatus according to any preceding Claim, wherein a proportion of the liquid flowing through the hollow threads passes outwards through the pores and vaporises or evaporates on the outer surface of the hollow threads.

15. An apparatus according to any preceding claims, wherein in addition to the heat transfer, filtration, micro-filtration, separation of material or exchange of material takes place through the porous hollow threads and/or simultaneous vaporisation or evaportion of the proportional of the liquid flowing through the porous hollow threads takes place on the outer surface of the porous hollow threads.

16. An apparatus for transferring heat as claimed in Claim 1 substantially as herein described with reference to any of the Figures of the accompanying drawings.

17. A hollow thread composed of synthetic polymers containing from 10 to 90% by volume of inter-communicating pores and an even surface having open pores, the proportion of the openings in the surface amounting to from 10 to 90% wherein a layer which acts as a membrane is applied to the hollow threads and/or the hollow threads contain graphite, metal particles, fillers, stabilisers additives, carbon black or dye pigments or any combination thereof and/or the hollow threads have a substantially circular cross-section with an external diameter falling within the range of 0.1 to 4 mm and/or the hollow threads have a wall thickness falling in the range of from 20 to 500 μm and/or the hollow threads are internally and/or externally profiled and/or the hollow threads have a cross-section which changes continuously or intermittently, in shape and/or size in its longitudinal direction and/or the hollow threads consist of two or more components and/or in that only a proportion of the components is porous.

18. A hollow thread according to Claim 17, wherein said layer which acts as a membrane is impermeable to fluid.

19. A hollow thread according to Claim 17 or 18 wherein the hollows have a cross-section which changes periodically continuous or intermittently.

20. An apparatus according to any of Claims 1 to 16 wherein the porous hollow threads comprise the features of Claims 17, 18 or 19 individually or in any combination.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1980. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

This Page is Inserted by IFW Indexing and Scanning Operations and is not part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☑ FADED TEXT OR DRAWING
- ☐ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☐ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: ______________________

IMAGES ARE BEST AVAILABLE COPY.
As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.